

# ANNALS OF SURGERY.

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## THE FIELD AND LIMITATION OF THE OPERATIVE SURGERY OF THE HUMAN BRAIN.<sup>1</sup>

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NINE years ago, while resident surgeon in a well known Philadelphia hospital, I watched a man die after a fracture of the cranium, and found at the autopsy, immediately under the fracture, a cerebral abscess, from the surface of which was extracted a piece of bone driven in at the time of injury. I had seen the vigorous man admitted; seen him first intelligent, scarcely sick perhaps; then confused and delirious, then comatose, and finally dead. As the elements of this human life were being successively extinguished by increasing destruction of nerve centres, the routine and approved medicinal treatment for encephalitis was steadily continued.

It took little surgical experience to recognize the lamentable result of the inactive, so-called conservative, treatment, which almost to a certainty sacrificed the patient's life. Do we, Mr. President and Fellows of this Association, know no better at this day than to allow life to be thus destroyed through an almost criminal neglect of the most evident indications for surgical interference?

The recollection of this case and of other similar ones has especially directed my attention to the importance of cerebral surgery; and it was with much pleasure that I accepted the president's appointment to prepare for this meeting a paper discussing the operative surgery of the human brain. The design of the paper is to indicate my views in such a succinct and categorical manner that the subsequent discussion may not

<sup>1</sup> Read by appointment at the annual meeting of the American Surgical Association, Washington, D. C., April 21st, 1885.

be discursive. The opinions and practice of the representative surgeons forming this body will thus, I trust, be so formulated that the profession at large may find in its Transactions definite rules of action. Dr. Moses Gunn,<sup>1</sup> and the present President, Dr. W. T. Briggs,<sup>2</sup> have at previous meetings given voice to their belief in more active surgical interference with pathological conditions of the brain. If their words had induced the profession to accept their conclusions, it is probable that I should not appear to-day to reiterate their thoughts. Since I began the collection of material for this paper, there has appeared the exhaustive article of my colleague, Dr. Charles B. Nancrede,<sup>3</sup> which leaves so little to be said that I was almost inclined to lay aside my pen.

Perhaps, however, constant agitation of the topic may at last gain for these surgical principles which I am about to advocate a wider professional acceptance. It is possible, indeed, that I may take a position rather more radical than that which the authorities mentioned will accept as justifiable. During my remarks I shall report some illustrative cases, but promise that no great amount of time shall be consumed in the relation of their details.

It will, perhaps, facilitate discussion if I at once announce the opinions that I hold upon more or less disputed points involved in the consideration of my subject.

My creed, if I may use the term, is as follows:—

I. The complexus of symptoms called "compression of the brain" is due not so much to displacing pressure exerted on the brain substance as it is to some form or degree of intracranial inflammation;

II. The conversion of a closed (simple) fracture of the cranium into an open (compound) fracture by incision of the scalp is, with the improved methods of treating wounds, attended with very little increased risk to life;

III. The removal of portions of the cranium by the trephine or other cutting instruments is, if properly done, at-

<sup>1</sup> Treatment of Fractures of the Skull, Recent and Chronic, with Depression, *Trans. Amer. Surg. Assn.*, Vol. I., p. 83.

<sup>2</sup> The Surgical Treatment of Epilepsy arising from Injuries of the Head, with special reference to the use of the Trephine, *Trans. Amer. Surg. Assn.*, Vol. II., p. 101.

<sup>3</sup> Injuries of the Head, *International Encyclopedia of Surgery*, Vol. V., pp. 1-109.

tended with but little more risk to life than amputation of a finger through the metacarpal bone ;

IV. In the majority of cranial fractures the inner table is more extensively shattered and splintered than the outer table ;

V. Perforation of the cranium is to be adopted as an exploratory measure almost as often as it is demanded for therapeutic reasons ;

VI. Drainage is more essential in wounds of the brain than in wounds of other structures ;

VII. Many regions of the cerebral hemispheres of man may be incised and excised with comparative impunity ;

VIII. Accidental or operative injuries to the cerebral membranes, meningeal arteries, or venous sinuses should be treated as are similar lesions of similar structures in other localities ;

IX. The results of the study of cerebral localization are more necessary to the conscientious surgeon than to the neurologist.

These propositions I shall consider successively :—

I. The complexus of symptoms called “compression of the brain” is due not so much to displacing pressure exerted on the brain substance as it is to some form or degree of intracranial inflammation.

Many have argued against the use of the trephine in depressed cranial fracture, because considerable depression may exist without interference with the cerebral functions and because “compression symptoms” frequently disappear after the lapse of a longer or shorter time, on account of the cerebrospinal fluid, as they put it, gradually becoming displaced or absorbed, and the circulation being restored to its natural condition,<sup>1</sup> and because deeper lesions beyond the reach of the trephine are frequently found in the fatal cases. Cure in these cases is supposed to occur by adaptation of the brain to the peripheral pressure. On the other hand, writers who favor more frequent operation have also clung to this compression theory, and have advocated perforation of the skull and elevation of the depressed bone for its relief. Their position has been assailed, and, I think, quite logically by those who use the line of argument mentioned above. Neither party seems

<sup>1</sup> H. B. Sands, *Annals of Anatomy and Surgery*, Vol. VIII. (1883), p. 104.

to see that the so-called "compression symptoms" after traumatism are not due to compression, but to some form or degree of inflammation. Let the profession repudiate the idea that brain displacement is the pathology of traumatic "compression of the brain," and many of the discordant opinions concerning the utility of trephining will be quickly harmonized. Some writers have, according to Stimson,<sup>1</sup> estimated that the constantly acting intra-cranial tension under normal circumstances is equal to from eight to twenty-five millimetres of mercury, and susceptible of temporary increase. This tension does in some instances overcome the displacement of the cranial vault. Duret,<sup>2</sup> after experimenting with injections of wax, states that a clot amounting to one-twelfth of the cranial capacity situated between the dura mater and the bone will cause coma and death in a few hours, but that in the arachnoid cavity a clot one-sixth or even one-fifth the bulk of the cranial cavity is requisite for a lethal effect. This results from the fact that in the latter case the wax moulds itself over a large surface, instead of being confined to one spot.<sup>3</sup> Lesion of the nerve centres must, of course, be absent. If this is true, how can any one believe that a square inch of bone depressed a quarter or a half of an inch will give sufficient pressure to cause cerebral symptoms, even if the presence of cerebro-spinal fluid does cause the external tension to be communicated to the entire cranial contents? Compression of the brain in cerebral tumors is the factor that causes many of the symptoms, but I am now speaking of surgical compression symptoms.

There are no definite symptoms by which we can distinguish accurately between laceration of the brain, contusion of the brain, and the so-called compression of the brain. Jonathan Hutchinson is almost correct in thinking that compression of the brain from depressed fragments of broken bone is an imaginary condition.<sup>4</sup> Briggs, with good reason, questions the view that secondary "compression symptoms" in intra-cranial suppuration are dependent exclusively upon the pressure of the

<sup>1</sup> *Treatise on Fractures*, p. 251.

<sup>2</sup> Quoted by Nancrede in *International Encyclopædia of Surgery*, Vol. V., p. 64.

<sup>3</sup> See Review of *Études Expérimentales sur les Traumatismes Cérébraux*, by H. Duret, in *Brain* (1878), Vol. I., p. 106.

<sup>4</sup> Statement of Briggs, *Annals Anatomy and Surgery*, Vol. VII. (1883), p. 65.

pus. He suggests, and I agree with him, that the symptoms are more probably produced by the inflammatory process which caused the formation of pus.<sup>1</sup> Dr. Hunter McGuire,<sup>2</sup> on the other hand, said at a recent meeting of this body: "If the fracture is a simple one, and the depression is not sufficient to bring on symptoms of compression, it is better to wait and see if the brain will not be able to accommodate itself to this condition." Here he admits a belief in the pressure theory, though in the next sentence he says that "we all know that there is no relation between the amount of depression and the symptoms of compression." At the same time Dr. D. W. Yandell<sup>3</sup> gave as his opinion that we should not elevate the depressed bone unless symptoms of compression are persistent. These opinions were given, I admit, several years ago, and the speakers may have changed their views by this time; but I am sure that to-day such words would still be spoken by many surgeons. The idea that depression of bone causes "compression symptoms" by mechanical pressure is deeply rooted. It would be well if traumatic "compression of the brain" were always translated "inflammation of the brain," and the profession taught to believe it due to irritation of the brain periphery from the traumatic cause.

II. The conversion of a closed (simple) fracture of the cranium into an open (compound) fracture by incision of the scalp, is with the improved methods of treating wounds, attended with very little increased risk to life.

Uncertainty as to the character of a cranial lesion is more dangerous to health and life than the conversion of a closed into an open fracture of the skull, because observation has taught the profession that open cranial fractures do not resemble in fatality similar open fractures of long bones. If I but learn the character of the skull injury, I am acquainted with surgical expedients that render restoration to health more probable than the complication due to the incision renders it improbable.

Antiseptic methods have done away with much of the danger of open bone wounds as is shown by the frequent advo-

<sup>1</sup> *Loc. Cit.*, p. 67.

<sup>2</sup> *Transactions*, Vol. I., p. 92.

<sup>3</sup> *Transactions*, p. 97.

cacy of resection for ununited and for malunited fractures, and of osteotomy and similar operations for conditions not urgently demanding surgical interference. No surgeon would hesitate to convert a closed recent fracture of the thigh or leg into an open one if it were otherwise impossible to replace fragments which were threatening life. Hence I strongly advocate exploratory incision of the scalp in obscure injuries of the skull.

Some months ago a man who, it was said, had fallen from a heavy wagon, and had been run over, was admitted into my ward of St. Mary's Hospital. Behind the left ear was a large hæmatoma, where, it was asserted, the wagon wheel had struck him. My resident surgeon made a two inch incision, and removed the clots; but finding no fracture, closed the wound with sutures and applied corrosive sublimate dressing. The knowledge that no fracture existed, was very satisfactory, I can assure you. Three days later, the incision had healed up without suppuration except in a space of  $\frac{1}{2}$  inch, and the sutures were removed. Such rapid union without complication will not always occur, but it shows the possibility of little risk in the majority of cases.

I recently ligated the brachial artery and never dressed the wound after the hour of operation, because it was healed when the dressing was first removed. Such results of antiseptic surgery make us properly bolder than our predecessors, who feared to convert a closed fracture of the skull into an open one.

III. The removal of portions of the cranium by the trephine or other cutting instruments is, if properly done, attended with but little more risk to life than amputation of a finger through the metacarpal bone.

Much of the mortality attributed to trephining belongs to the serious brain-lesions that have accompanied the fractures for which trephining has been done, and to the absence of proper surgical antiseptics. Many patients have been trephined, and have undoubtedly died; but the opponents of trephining must show that cause of death lay in the operation itself. In deaths occurring from lesions for which trephining

is the admitted treatment, they must likewise show that the operation was done early enough to remove the causative factor of death before they can assert that the operation was unavailing. Gross, Michel and many others have frequently quoted historical facts and cases, which show the slight risk incurred by uncomplicated trephining. Briggs says: "My opinion, based on a large personal experience, is that trephining the skull is one of the safest of the capital operations of surgery."<sup>1</sup>

The opposite view, however, was held by Dr. H. F. Campbell, at a recent meeting of this Association, at which he said: "I have ever regarded trephining as one of the most serious of all capital operations."<sup>2</sup>

Nanerede,<sup>3</sup> from a careful investigation, gives a mortality of 10.69 per cent. as being a probably fair estimate of the risk of the operation, *per se*, and a death rate of 15.29 per cent. as an expression of the probable risk in trephining a simple depressed fracture. This author further says that his own experience has taught him that trephining is not a dangerous operation, and that more patients die from complications, that might have been prevented by timely operation, than from the removal of a disc of healthy bone.

Dr. R. W. Amidon, of New York, has collected 115 cases of trephining and kindred operations occurring since 1879. These operations were done for various causes, and were unselected by Dr. Amidon; nor did he confine himself to cases treated antiseptically.<sup>4</sup> Of these 115 unselected cases, 29 died; but of these, 25 presented, at the time of operation, symptoms endangering life, leaving therefore but 4 cases in which the fatal issue could be attributed to the operation. This gives a mortality of a little over 3 per cent. to the operation. He announces his reasons for considering the 25 deaths as not attributable to operation in the following words: "In six cases symptoms of abscess of the brain declared themselves before the operation, was performed. In five a meningitis ex-

<sup>1</sup> *Annals of Anatomy and Surgery*. Vol. VII., 1883, p. 65.

<sup>2</sup> *Transactions*. Vol. I., p. 94.

<sup>3</sup> *International Encyclopædia of Surgery*. Vol. V., pp. 94 and 95.

<sup>4</sup> *Annals of Surgery*, St. Louis, March, 1885, p. 205. See also his previous paper, *Medical News*, June 21, 1884.

isted at the time of operation. In four cases shock caused death; two died of hemorrhage from a branch of the middle meningeal artery (not wounded in the operation); one died of hemorrhage from the middle cerebral artery, severed by a stab wound of the head; one died of hemorrhage from a lacerated longitudinal sinus; one of galloping consumption, which was hereditary; one of pneumonia; one of extensive laceration of the brain; one of opium poisoning; and three I accept, on authority of the physician reporting them, as not dying from the effects of the operation."<sup>1</sup>

Yeo<sup>2</sup> trephined 26 monkeys under antiseptic precautions, and had only one death attributable to intracranial inflammation, though six other deaths from exposure to cold weather, chloroform poisoning or hemorrhage occurred among his cases. In some of the animals portions of the brain were excised. Of other monkeys trephined without antiseptic precautions, all died.

Much stress has been laid by some writers on the danger of wounding the membranes and brain with the trephine. With a conical trephine or the burr of the surgical engine as recommended by Dorr and myself,<sup>3</sup> there is no danger of this. Even if such an accident should occur to the membranes it is, in my opinion, of very minor importance, unless the damage is much greater than could occur except by gross carelessness. Dr. Gunn disapproves of the use of the mallet and chisel because he believes that the repeated shocks to the brain may prove injurious to the nerve tissues.<sup>4</sup> For removing large or irregular areas of bone the flat burr of the surgical engine is certainly much more accurate and desirable.

I have compared trephining with amputations through the metacarpal bone, because in both operations, there is exposure of cancellated bone structure. I do not know that the mortality of such finger amputations has been accurately computed, but it is certainly regarded by all as slight. It is seldom that

<sup>1</sup> This list accounts for the death of 26 instead of 25 patients, and apparently contains an error.

<sup>2</sup> *British Medical Journal*, May 14, 1881, p. 763.

<sup>3</sup> *Buffalo Medical and Surgical Journal*, XIX., p. 475. *Philadelphia Medical Times*, 1881-'82, XII., 206.

<sup>4</sup> *Transactions*. Vol. I., p. 88.



patients are confined to the house after such amputations. Trephining in itself is, I am convinced, little, if any more hazardous. I believe that one of us trephined to-day, might, if it was necessary, go home without incurring any great risk to life; though I would not advise such a procedure. Amputation of the finger may be followed by erysipelas, septicæmia, or death; so may trephining, but it is not to be expected. The mortality of amputations of the thumb and fingers is, according to Ashhurst,<sup>1</sup> 3.3 per cent. This undoubtedly is less than the mortality of amputations through the metacarpus, because amputation of distal phalanges, which are almost without risk, are, of course, included. The same writer gives partial amputations of the hand a mortality of 6.6 per cent. If, therefore, we estimate amputation of a single finger through the metacarpal bone as having a mortality of 4 or 5 per cent. it will probably be nearly correct. According to the figures of Amidon, given above, trephining is actually much less dangerous to life than this.

IV. In the majority of cranial fractures the inner table is more extensively shattered and splintered than the outer table.

Many experimental fractures made in the dissecting room, and observation of cases in the practice of myself and of others, teach me that extensive shattering of the inner table, with only a moderate amount of fracturing of the external table, is of frequent occurrence in other as well as in punctured fractures. I admit that the condition in the cadaver, preserved by zinc chloride, with its shrunken brain, is different from that in the living; but there is much evidence of the same splintering to be found in the study of accidental and homicidal cranial fractures. This is in accordance with the well-known mechanical law that compressing force applied to the outside of a surface, as undoubtedly most fracturing forces applied to the skull are, tends to produce more extensive breaking of the inner surface. This is especially so in all localized blows. Punctured fractures have long been treated by early trephining, to avert encephalitis. For the same reason I recommend resort to trephining even in more diffused and less accentuated fractures.

<sup>1</sup> *International Encyclopedia of Surgery*, Vol. I., p. 637.

It is to prevent inflammatory sequences due to splinters forced into the membranes and brain, and to avert the consecutive occurrence of epilepsy and insanity, that the operation should be performed; not because of the fear that symptoms of compression of the brain may arise, nor because necrosis of detached portions of bone may occur.

Sometimes there is no fissure in the outer table, though the inner table is extensively broken and depressed. Twenty such cases are reported as having occurred during the late civil war.<sup>1</sup> All of these patients died from intracranial inflammation except one in which the splintered portion of the brain table was removed as a sequestrum. Prescott Hewitt and Lidell have furnished other statistics of such cases.<sup>2</sup>

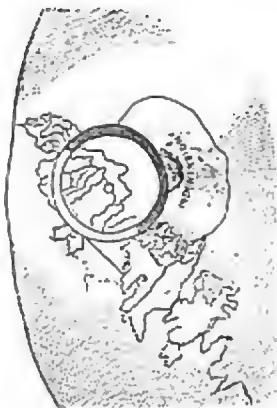


Fig. 1. Outer surface of fractured skull.

I show you a piece of skull removed from a patient who recently died under my care. He was struck with a pitcher which caused a small scalp wound, through which my finger tip felt rough bone. I enlarged the incision, came upon a very rough surface, due to unusual irregularity of the lambdoidal suture with small Wormian bones, and found only a small dent or fissure looking much like the entrance for a vein. I determined

<sup>1</sup> *Med. and Surg. History Rec.*, Pt. I., Surgical Volume, p. 150.

<sup>2</sup> *Holmes's System of Surgery*, Am. Edition, 1881. Vol. I., p. 636.

to do exploratory trephining because of the nature of the vulnerating force. Dr. George Dock, under my direction, cut out a disk of bone close to the external dent at the position which was thought would give best access to any splinters. Nothing was found but a small fissure crossing the inner surface of the disk. A probe slipped between the inner table and the dura disclosed no irregularity; therefore, no further operative steps were taken. A portion of the inner table left in the bottom of the trephine-hole was undisturbed because it was smooth. The patient died in about 42 hours of delirium tremens. Dr. H. F. Formad, the pathologist, found no inflammation of brain or meninges, but intense  $\alpha$ dema of the brain and membranes, and at the inquest swore that death occurred from alcoholic delirium. The section of bone presented to you shows a marked



Fig. 2. Inner surface of fractured skull.

depression of the table due to a T-shaped fracture under the seat of the external dent, beneath which was a small clot upon the dura mater. The top line of the T, which in the figure is vertical, is  $1\frac{1}{4}$  inches long. The cleansed bone shows what was not seen at the time of operation, because the surface was at that distance from the wound left covered by periosteum, a semi-elliptical fissure of the external table encircling the slight dent. It would have been better if the trephine had been ap-

plied directly over the external dent instead of alongside of it. It is well, therefore, to follow that well-known rule in such cases as this, and also to employ a large trephine. Where a mere entrance for the elevator is desired, a small trephine should be used.

If this patient had lived he would have been very liable, I think, to epilepsy or insanity. Only a few weeks ago I saw, in consultation with Dr. Charles K. Mills, a man of 22 years, who was suffering with marked mental impairment occurring, as he and his brother said, subsequent to a fracture of the skull received about four years previously. Reference to the notes of the Pennsylvania Hospital, in which he had been treated, showed that he had been admitted for a compound depressed fracture of the skull, which was so slightly marked that operation was not deemed necessary. It is probable that his mental impairment was due to a depression similar to that seen in this specimen. It was my intention to trephine in this case of mental failure if further investigation of his condition by Dr. Mills conclusively traced the aberration to the injury. Unfortunately the patient passed out of our control by returning to his country home before I had a second opportunity of examination.

I feel sure that the element of danger in skull fractures is this splintering of the inner table; and I differ most decidedly from those who esteem it of comparatively little importance. Its danger in those abruptly depressed fractures called punctured fractures has been quite generally recognized; but its great frequency and risk in other forms of fracture are still not sufficiently emphasized by all authorities. Ashhurst in the last edition of his *Surgery* dated 1882,<sup>1</sup> says in speaking of simple depressed fractures: "I have never seen a case of this kind in which I thought the use of the trephine justifiable, nor an autopsy which showed that the operation could possibly have saved life."

Concerning compound depressed *impacted* fractures he would not advise operation "even if symptoms of compression were present." He goes on to say that the trephine "is not to be used with the idea of relieving compression, nor with the idea that there is any special virtue in the operation to prevent encephalitis." In punctured fracture the same distinguished sur-

<sup>1</sup> Pp. 325 and 326.

geon thinks the trephine may be necessary to slightly enlarge the opening in the skull to remove the spicules which are apt to be broken from the more extensively involved internal table; but says: "It is better to leave imbedded in the brain, a foreign body, or even a fragment of bone, than to add to existing irritation by reckless attempts at its removal."

Perhaps Dr. Ashhurst has changed his views within the last two years. If he has not, I must disagree with him on this subject; except in the opinion that reckless surgery is always unjustifiable. His definition of what constitutes reckless surgery may differ from mine.

Many writers while admitting the probability of greater damage to the inner table, do not give its disastrous consequences sufficient stress. Briggs,<sup>1</sup> however, truly says, that the great danger in depressed fracture is not compression, but inflammation set up by displaced fragments of bone. Dr. Sands says<sup>2</sup> that advocacy of early trephining on the ground that loose pieces of bone in simple comminuted fracture will probably become necrosed and set up fatal intracranial inflammation, is improper. I believe that few advocates of early trephining give necrosis as a reason for their belief. Necrosis is not, but encephalitis is, very liable to occur.

Dr. Sands also believes that the apprehensions felt by those who advocate preventive trephining in closed depressed fracture, without head symptoms, with the object of removing sharp fragments of the inner table, are scarcely justified by observation. These extensive osseous lesions are, in his opinion, often recovered from, without surgical interference. He states that<sup>3</sup> immediate resort to the trephine is imperatively required, however, in fractures of limited extent and in which there is reason to think, from its situation or the occurrence of monoplegia, monospasm, or hemiplegia, that a splinter has penetrated the motor area of the cortex. Trephining is also demanded, in Dr. Sands's opinion when compression of the brain is due to blood between the dura and cranium.

V. Perforation of the cranium is to be adopted as an explor-

<sup>1</sup> *Annals of Anatomy and Surgery.* Vol. VII., p. 69.

<sup>2</sup> *Annals of Anatomy and Surgery.* Vol. VIII., 1883, pp. 101-103.

<sup>3</sup> *Annals of Anatomy and Surgery.* Vol. VIII., 1883, p. 106.

atory measure almost as often as it is demanded for therapeutic reasons.

I have shown that the occurrence of fatal encephalitis is frequently due to spiculation of the inner table, and that spiculation or extensive shattering of the inner table is common in limited fractures of the external table. Hence it follows that exploratory perforation of the cranium is justifiable in all cases where the nature of the impinging force or the appearance of the external table renders spiculation of the inner table probable; provided that less danger to life and health is inherent in perforation than in the probable spiculation. I have already asserted my belief in, and given reasons for, a low mortality risk of perforation. I am of the opinion that fractures of the cranial vault produced by such general application of force as occurs when a man falls from a great height upon his head, are less frequent than fractures by direct and comparatively localized blows such as occur from missiles, bullets and falls from low elevations. These latter are those which tend to produce internal spiculation. Hence I am driven to the conclusion that exploratory perforation to determine the absence or presence of internal spiculation is often demanded by the uncertainty of the invisible condition. Without a knowledge of the true state of affairs treatment is empirical; and the risk to subsequent mental health or to life is too great to permit reliance on empirical treatment when a knowledge of the true condition is obtainable with the slight danger that pertains to antiseptic trephining.

Whenever the fracture, whether originally an open one or so made by my incision, presents the possibility of the inner table being detached and splintered more extensively than the outer, I should be inclined to advise perforation. In other words I would cut the scalp to see the condition of the outer table and I would cut the bone to see the condition of the inner table, in every case where the risk of obscure knowledge is greater than the risk of divided scalp and perforated bone.

The tendency to procrastination in such matters has destroyed many lives. Nanerode<sup>1</sup> recommends early preventive trephining strongly, because, after encephalitis has once

<sup>1</sup> *International Encyclopedia of Surgery*. Vol. V., p. 95.

begun, trephining does not remove the inflammation, but merely one source of irritation without influencing the existence of the inflammatory process which has been aroused. His statistics show the mortality of the operation, after symptoms of brain disease have arisen, to be much more than twice as great as in preventive operations. The figures are 52.8 per cent., and 22 per cent. He further says that although the operation should be done early, it is never too late to make the attempt in neglected cases; for an abscess may be found and evacuated with the result of saving life. Stimson<sup>1</sup> says that the percentage of recovery in early operative interference is actually high compared with tardy operations; and cites instructive cases to prove that his opinion is correct. Wound of the longitudinal sinus and removal of about three square inches of bone was no bar to recovery in a case which he treated by immediate trephining, though no brain symptoms except stunning were present.

VI. Drainage is more essential in wounds of the brain than in wounds of other structures.

That drainage is as essential in wounds of the brain as in wounds of other structures would seem to be a self-evident proposition; and yet gunshot and other wounds of the skull and of the cerebral membranes and hemispheres have long been treated as if drainage was not a necessary factor in therapeutics. A surgeon who would think himself censurable to leave the opening leading into a suppurating cavity obstructed by shreds of skin and fascia, will, with profound equanimity, see his patient die with pus burrowing among the vital centers of the brain. There may be but a small fissure or opening, or perhaps none at all, in the bony wall enclosing the brain, and but a mere puncture in the tense dura mater, yet he will hesitate to give free exit to the pus. We split open a knee joint, we incise a pleural, peritoneal, or pericardial cavity to give free egress to pus; so must we cut away the cranium and incise the dura mater in analogous conditions. The greatest error in this connection has perhaps been in an expectant instead of an operative treatment of bullet wounds of the brain.

<sup>1</sup> *Treatise on Fractures*, p. 248.

Stimson,<sup>1</sup> in speaking of the trephine, says: "Most writers upon surgery during the last twenty or thirty years condemn its use unequivocally except in compound fractures with depression and with marked and persistent cerebral symptoms." A very few writers could be mentioned who are not included in the class spoken of by Stimson, but who have advocated more frequent use of the trephine in such skull fractures as are seen in civil practice. The hesitation to employ the trephine in gunshot fractures, however, has been almost universal.

This is, I think, very erroneous doctrine, for death from abscess is very common after bullet wounds of the brain. The fracture is compound, the suppurative process recognized as almost certain to occur, and yet no provision of moment has, according to the usually pursued treatment, been made for drainage and antisepsis.

In a considerable number of open fractures of the cranium of a linear kind pus has been found at the autopsy beneath the bone or membranes. The danger of an early trephining in such cases would have been less than that resulting from the imprisoned pus. The mere line of fracture establishes a direct communication, between the air and the membranes, which may lead to suppuration. Such communication is, of course, much more extensive in gunshot fractures and comminuted fractures. In cases, therefore, where there is reason to believe that suppuration will occur, trephining may be beneficial for purposes of drainage. I do not advocate perforation in all linear fractures which are not subcutaneous; but advise it when there is such strong probability of suppuration as is the case in nearly all gunshot fractures.

The statistics of H. R. Wharton,<sup>2</sup> concerning foreign bodies lodged in the brain show the importance of removal when possible. Of 106 cases in which removal was accomplished, only 34 died; of 210 cases, in which no attempt at removal was made, 122 died. The death rate here was doubtless largely due to want of proper drainage.

While preparing this paper I assisted Dr. R. J. Levis in a case which will illustrate this phase of my communication.

<sup>1</sup> *Treatise on Fractures*, p. 247.

<sup>2</sup> *Philadelphia Medical Times*, July 19, 1879.



A young man of 19 years was shot in October, 1884, with a pistol of 22 hundredths calibre held about a foot from his head. The ball entered the skull at a point about  $1\frac{1}{2}$  inches behind and  $2\frac{1}{2}$  inches above the cartilaginous attachment of the left ear, taking a direction slightly downward. He fell senseless, but soon reacted. The next day when seen he had no fever, no palsy, no strabismus, no abnormality of pupils, and no intellectual obscurity. Towards evening, however, his sight began to decrease, and by the morning of the second day after the accident he was totally blind, and had no pupillary reaction to light. Dr. A. H. McAdam asked Dr. Levis to assist him in the treatment of the case. A probe carefully inserted into the skull entered for a distance of about  $3\frac{1}{2}$  inches. The following afternoon (third day) Dr. Levis trephined for the purpose of affording free drainage and of attempting extraction of the bullet, which he thought he possibly felt with the probe. An opening was made, the membranes incised, and several spicules of bone extracted from the cerebral hemisphere into which they had been driven by the ball. The brain substance was already so broken down that it oozed out before the disc of bone was cut entirely loose, and the full length of my little finger was readily carried into the brain wound. The ball, being not readily found, was not searched for very long. On the next day (fourth) the patient could distinguish the hand passed before his eyes. Two days later he could see to roughly tell the time by a large clock hanging across the small room.

After the lapse of two more days, according to the notes of the case, he could tell the minutes indicated by the clock, which had a dial about ten inches in diameter, and was about six feet distant from him. Vision seemed better in the left than in the right eye, and when looking he closed the right eye, as if some diplopia existed. Free suppuration from the wound continued, no marked febrile action occurred, and subsequently he became able to tell time by a watch. Nine weeks after the injury there occurred an abscess at the site of the trephining, but three months subsequent to the shooting he was attending to his business in good health, though the wound had not yet cicatrized. He could see well. I saw the patient only at the time of the operation, and have taken these facts from notes obtained by Dr. C. L. Bower.

I examined this patient in April, 1885, six and a half months after injury. He was in good health, weighed 20 pounds more than usual, drove a wagon which he loaded with baskets and bundles, and had as good a memory as ever for numbers, names and words. No failure in this respect was noticed by him in his occupation of delivering goods. He had no headache, and no tenderness or pain at the cicatrix in the

scalp. I found that his left ear heard my watch tick at 24 inches, while his right heard it at 42 inches. This defect in hearing he had observed, and seemed to attribute it to the injury. He whistled well, but protruded the tongue with its tip a little to the left. No loss of tactile sense did I discover in testing sensation of the fingers with the points of a pair of compasses. He never observed trouble in vision before the injury, but said that now he could not read the newspaper well. The pupils reacted to light, and were not dilated nor contracted. The right eye showed vision  $\frac{2}{2}$ , not perceptibly improved by spherical lenses or the stenopæic hole; the left eye  $\frac{2}{2}$  not perceptibly improved by spherical lenses or the stenopæic hole. He read D1.25 at 4½ inches with difficulty, which convex lenses did not remove to any marked degree. No diplopia was noticed by him when looking at lights or stars. No strabismus and no insufficiency of the internal rectus muscles were observed by me. There was, however, hemianopia of both eyes when a pencil was held to the right of the middle line of each eye. The sense of smell in each nostril was apparently unaffected, for he easily distinguished carbolic acid from cologne water. On each side of the tip of the tongue he readily distinguished tannin from chloride of ammonium. I regret that I had not a good opportunity of examining the ears and eyes with otoscope and ophthalmoscope.

While admitting that similar cases might have recovered without operation, I doubt its probability; the spicules driven into the brain, the softening therein already begun, and the profuse suppuration through the perforation make me believe that early death from intra-cranial abscess would have killed the patient rapidly if no operation had been done.

Agnew<sup>1</sup> quotes MacLeod as saying that in the Crimean war, of 67 gunshot fractures of the skull, in which the skull was penetrated, one hundred per cent. died. Agnew himself gives a table (p. 288) of 486 cases of penetrating gunshot fracture, with a mortality of 85.5 per cent. These high death rates are largely, I believe, due to inefficient drainage; but also to splintering of the inner table and driving of the splinters into the brain substances. Dr. S. W. Gross is quoted by Dr. C. D. Gross as showing in over seven hundred cases of gunshot wounds of the skull only 25+ per cent. of recoveries by expectant or conservative treatment, but 41+ per cent. recoveries after operative treatment; or a difference of about 16

<sup>1</sup> *Principles and Practice of Surgery*, Vol. I., p. 287.

per cent. in favor of operative interference. These statistics of Gross<sup>1</sup> were published eighteen years ago, and would probably be improved by the present operative methods.

Drainage of cerebral abscesses and wounds by tubes or horse hair has been successfully performed on several occasions. Noyes<sup>2</sup> passed a drainage tube through a traumatic abscess in the frontal lobe, utilizing the trephine hole and the orbit for its entrance and exit. In this case death occurred. The four cases of similar operative treatment reported by Burchard, by Fluhler,<sup>3</sup> by Fenger and Lee,<sup>4</sup> and Kemper,<sup>5</sup> all recovered. Dr. J. P. Thomas,<sup>6</sup> of Kentucky, reports a case of cerebral abscess, which he successfully treated in 1875 by drainage obtained by position and the use of tents made of strands of silk.

These cases are sufficient to prove the truth of my sixth proposition.

VII. Many regions of the cerebral hemispheres of man may be incised and excised with comparative impunity.

Physiological experimenters know well that the lower animals bear, without serious risk to life, ablation of quite large areas of the brain substance. Although clinical experience has shown the same fact respecting the human brain, surgeons have not been sufficiently impressed with the circumstance. They have looked upon the brain and its membranes very much, as until recently, they looked upon the heart and pericardium—a region never to be approached with trocar or scalpel. Many patients have died of brain abscess or brain tumor, because the timidity of the surgeon prevented the introduction of an aspirating needle or knife to open the pus cavity, or the employment of enucleation for the detachment of a neoplastic growth. This is partly due to the ignorance of surgeons respecting the localization of cerebral functions.

<sup>1</sup> *System Surgery*, Ed. 1882, Vol. II., p. 71, from *Am. Jour. Med. Sciences*, October, 1867.

<sup>2</sup> *Am. Jour. Med. Sciences*, July, 1882.

<sup>3</sup> *Med. News*, January 10, 1885, and *New York Med. Journal*, March 28, 1885.

<sup>4</sup> *Transactions*, 1884, and *Am. Jour. Med. Sciences*, July, 1884.

<sup>5</sup> *Am. Jour. Med. Sciences*, January, 1885.

<sup>6</sup> *Med. News*, February 14, 1885.

Nancrede reports<sup>1</sup> a remarkable case, in which a patient who was thought to be dead from cerebral abscess following penetration of the skull by a knife, was restored to consciousness by a second trephining and incision of the brain substance. An aspirator needle had previously been passed several times into the brain to the depth of two-thirds of an inch through the first trephine hole, but no pus had been passed. After the incision had evacuated one or two fluid ounces of pus the man revived and lived till the sixth day.

Dupuytren, Detmold, J. F. Weeds, Hulke and others have reported recoveries after incision of the brain and evacuation of abscesses.

Nancrede finds out of thirty cases of cerebral abscess treated by operation a mortality of only 50 per cent. I do not know in how many of these cases the brain substance was incised or punctured in the search for pus.

Amidon<sup>2</sup> states that of 100 cases of operation on the head, collected by him during recent years, the dura mater was opened in 33, by either the injury or the surgeon. These gave a mortality of 39.3 per cent.; but he states that in only one death could the fatal issue be directly ascribed to the exposure of the cerebral convolutions, and therefore he gives the mortality of operation inducing exposure of the hemispheres of the brain as 7.6 per cent. As showing the tolerance of the brain substance to injury, he quotes, among others, the following recent cases, of which he gives the various sources, as below mentioned.

*Fluhrer's case.* A bullet entering at a point about four centimetres above the left eye, a little to the left of the median line, pierced the first frontal convolution, traversed the brain backwards and a little outwards, and emerged from the upper part of the parietal lobule, where it lay slightly imbedded in the brain. The symptoms were not alarming. The course of the bullet was ascertained by careful probing, and the trephine was applied over the supposed site of the ball. After a short search it was found, and a drainage apparatus composed of horse hair and catgut passed through the entire track of the ball. The operation was done with antiseptic precautions, and the wounds were dressed with iodoform. Recovery was uninterrupted and complete. The slight weakness of the right hand and loss of memory rapidly disappeared.<sup>3</sup>

<sup>1</sup> *International Encyclopedia of Surgery*, Vol. V., p. 83, and *Transactions*, 1884.

<sup>2</sup> *Medical News*, June 21, 1884.

<sup>3</sup> Case of Dr. Wm. F. Fluhrer, unpublished, quoted by permission given Dr. Amidon; since published with most valuable remarks in *New York Medical Journal*, March 28, 1885.

*Olpherts' case.*<sup>1</sup> The whole of the right parietal, parts of the right occipital, temporal, and left parietal bones was torn away, with extensive laceration and loss of cerebral substance. The case was treated antiseptically without operation, and recovered perfectly.

*Wood's case.*<sup>2</sup> A man was struck by the pilot of an engine, and his head cut open from the inner canthus of the left eye to the occiput. A furrow eight centimetres long was cut in the anterior lobe of the left hemisphere. Under cold applications he recovered.

*Hoskins' case.*<sup>3</sup> A boy six years of age was stepped on by a horse. The left side of the head was crushed in, blood, bone and brain escaping. Blood and pieces of brain exuded from left ear. It was estimated that 62 cc. of cerebral substance were lost. There were three compound fractures. There was a right hemiplegia, which disappeared, and aphasia, which improved.

These cases certainly prove the truth of my seventh proposition, as would also seem self evident from the occasional continuation of life and even of comparative health during the existence of large areas of brain softening or suppuration, or of large substitutive growths in the cranial cavity.

VIII. Accidental or operative injuries to the cerebral membranes, meningeal arteries, or venous sinuses, should be treated as are similar lesions of similar structures in other localities.

Numerous cases have recently been reported that prove this assertion. W. T. Bull<sup>4</sup> obtained good results in two cases after suturing the divided dura mater with catgut; Parkes<sup>5</sup> had a cure following lateral suture of the superior longitudinal sinus; W. Hopkins,<sup>6</sup> of Philadelphia, recently treated successfully a profuse hemorrhage from the superior longitudinal sinus, after removing comminuted bone, by pressure with a pad of lint sprinkled with iodoform; Sands<sup>7</sup> applied pressure to a wounded superior longitudinal sinus; Brinton<sup>8</sup> has applied lateral ligature successfully to the lateral sinus; Nancrede<sup>9</sup> has

<sup>1</sup> Olpherts, *Br. Med. Jour.* (1882), II., 89.

<sup>2</sup> Wood, *Am. Jour. Med. Sciences*, July, 1881, LXXII., 168.

<sup>3</sup> Hoskins, *Lancet* (1883), II., 99.

<sup>4</sup> *Archives of Medicine*, Vol. I. (1879), p. 219.

<sup>5</sup> *Annals of Anatomy and Surgery*, Vol. VIII. (1883), p. 118.

<sup>6</sup> *Annals of Surgery*, July, 1885.

<sup>7</sup> *Annals Anatomy and Surgery*, Vol. VIII. (1883).

<sup>8</sup> *Philadelphia Medical Times* (1881), Vol. XII., p. 577.

<sup>9</sup> *Philadelphia Medical Times*, March 8, 1884, Vol. XLV., p. 440.

successfully ligated the middle meningeal artery. Numerous other cases of this sort might be cited, but enough have been quoted to prove my proposition.

[To be continued.]

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## AN EXPERIMENTAL AND CLINICAL STUDY OF AIR-EMBOLISM.

[Continued.<sup>1</sup>]

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### VIII. IMMEDIATE CAUSE OF DEATH AFTER INTRA-VEINOUS INSUFFLATION OF AIR.

VARIOUS theories have been advanced to explain the injurious effect of the presence of air in the circulation. Bichât (*Physiological Researches on Life and Death*, p. 186) attributed death resulting from intra-venous injection of air to cerebral anæmia produced by the presence of air in the cerebral vessels, asserting at the same time that a very small quantity would suffice to produce this effect. As the first argument in favor of this view, he claims that the heart continues to beat for some time after the cessation of animal life. Secondly, air injected through one of the carotids produces death in the same way as when introduced into the veins. Thirdly, the cases reported by Morgagni, where death was attributed to the presence of air which was found in the cerebral vessels at the post-mortem examination, and which was supposed to have developed there spontaneously. Fourthly, all examinations after death revealed the presence of frothy blood, mixed with air-bubbles, in both ventricles. Fifthly, air

<sup>1</sup> Continued from Vol. I., p. 549, June, 1885.